



Microturbines

**US DoE DER Roadshow
October, 2003**

Ingersoll-Rand

What Is A Microturbine?

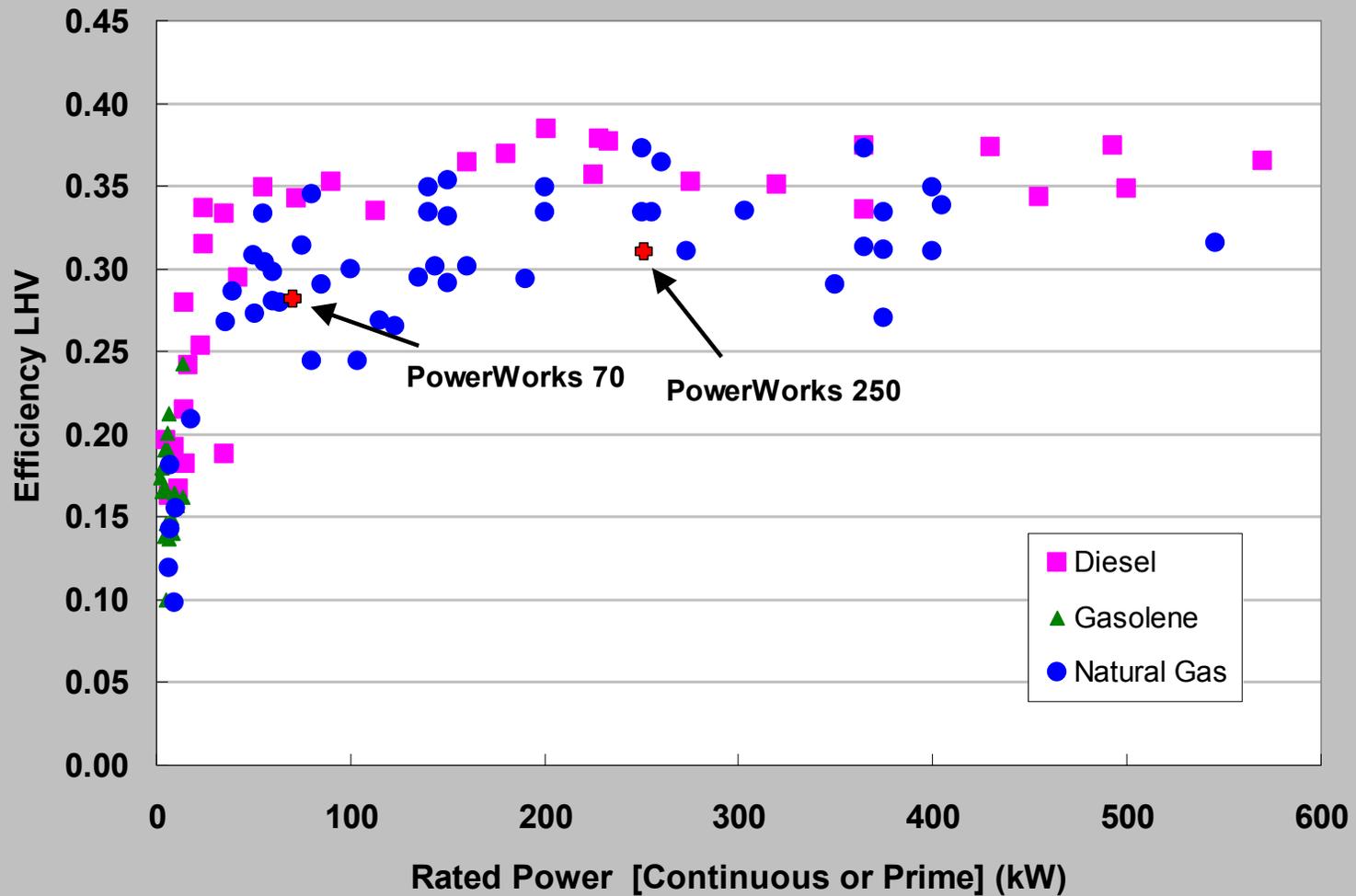
- Microturbines: a new way to locally supply continuous energy to facility
- Installed inside or near a building to provide electricity and optionally, heat
- Similar to a placing a furnace, boiler, backup genset, or chiller in a facility



Microturbine Advantages

- Clean electricity
- Very low emissions
- Quiet operation
- Low maintenance
- Long engine life
- Good system efficiency
- Multi-fuel operation
- Cogeneration heat

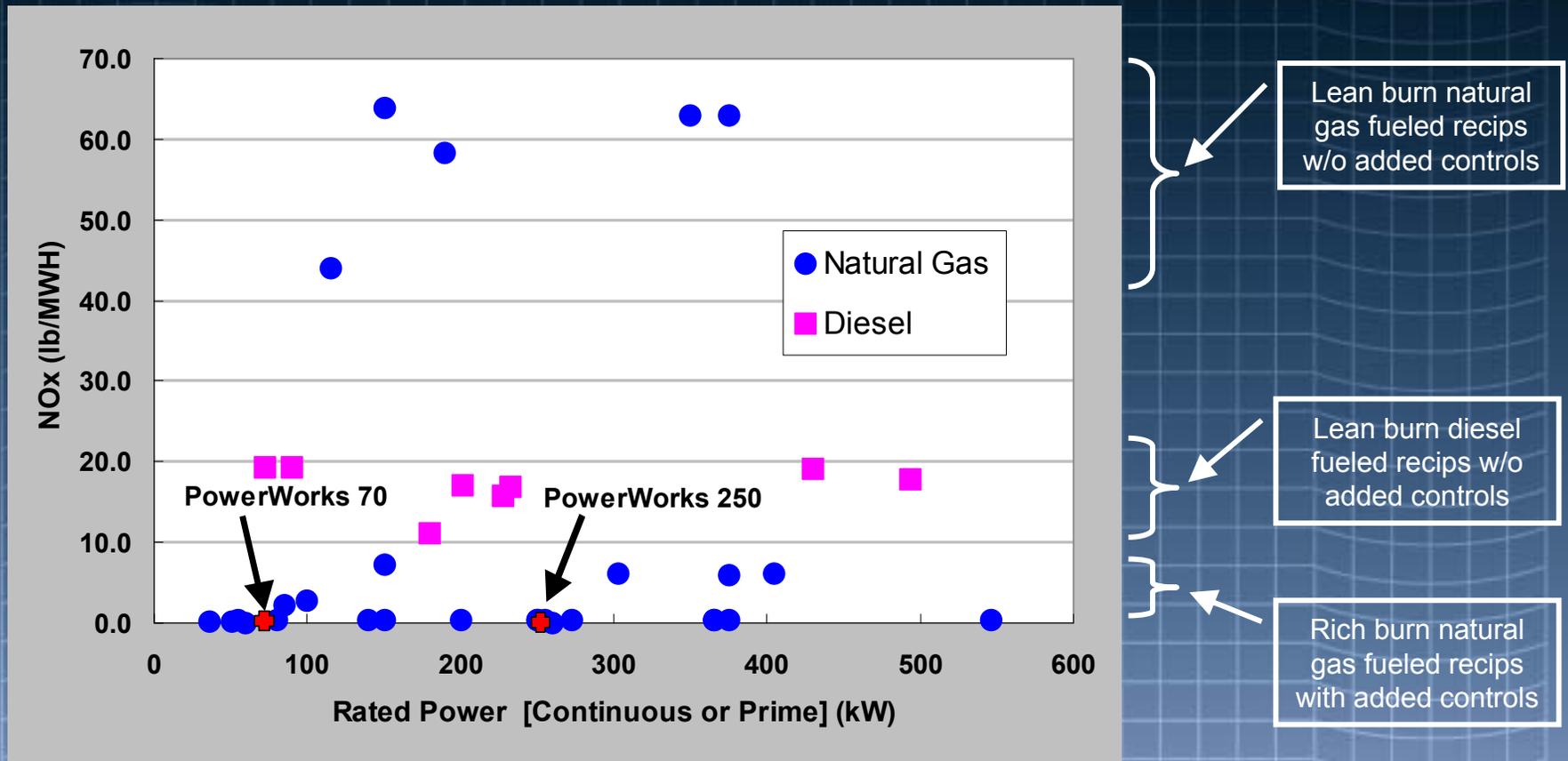
Microturbine versus Recip Efficiency



Low Emissions Combustion

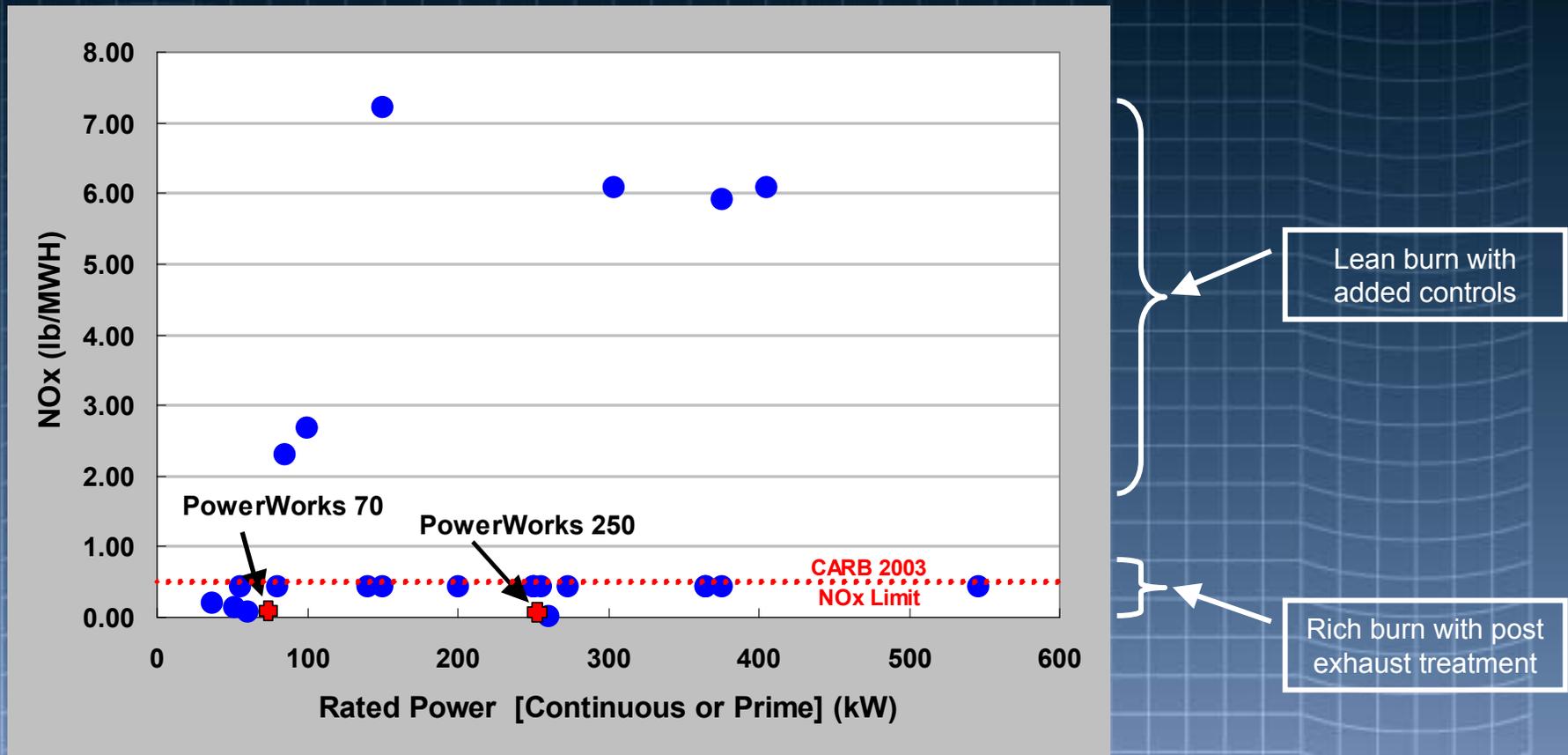
- 70kW Specification at ISO Conditions:
 - NO_x <0.41 lb/MWh (<9 ppmv @ 15% excess O₂)
 - CO <0.25 lb/MWh (<9 ppmv @ 15% excess O₂)
- 2003 California Air Resource Board Limits:
 - NO_x <0.5 lb/MWh
 - CO <6.0 lb/MWh
 - VOC <1.0 lb/MWh
- Preliminary certification testing of 70LM:
 - NO_x <0.15 lb/MWh
 - CO <0.25 lb/MWh
 - VOC <0.05 lb/MWh
- Testing by outside agencies confirms low levels

Typical Emissions by Size



“Prime” or “continuous” duty power ratings @100% load
Based on Manufacturer’s published specifications

Natural Gas Fueled Reciprocating Engines With Emissions Controls



“Prime” or “continuous” duty power ratings @100% load
Based on Manufacturer’s published specifications

Ingersoll-Rand 70kW Microturbine Key Features

Patented Combustor

- Dry low NOx
- Easily meets stringent environmental regulations

Two-Shaft Engine

- Reduces stress for longer life

Proven Generator Technology

- Well understood by utilities
- Same technology used by utilities to power the grid

Patented Recuperator

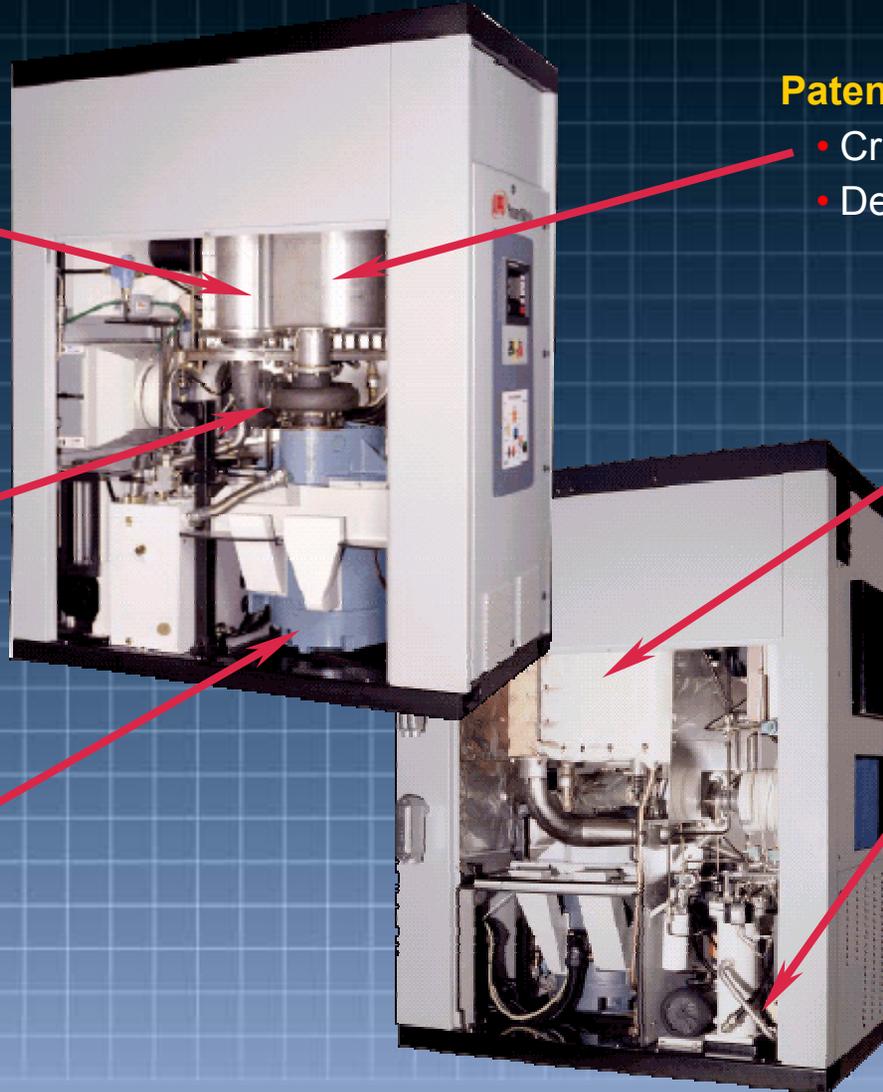
- Critical to high efficiency
- Designed for 80,000 hour life

Integrated Heat Recovery

- Smaller footprint
- Controllable output level

Fuel Gas Booster

- Long-life design
- Fully integrated
- IR technology already used in thousands of critical industrial applications

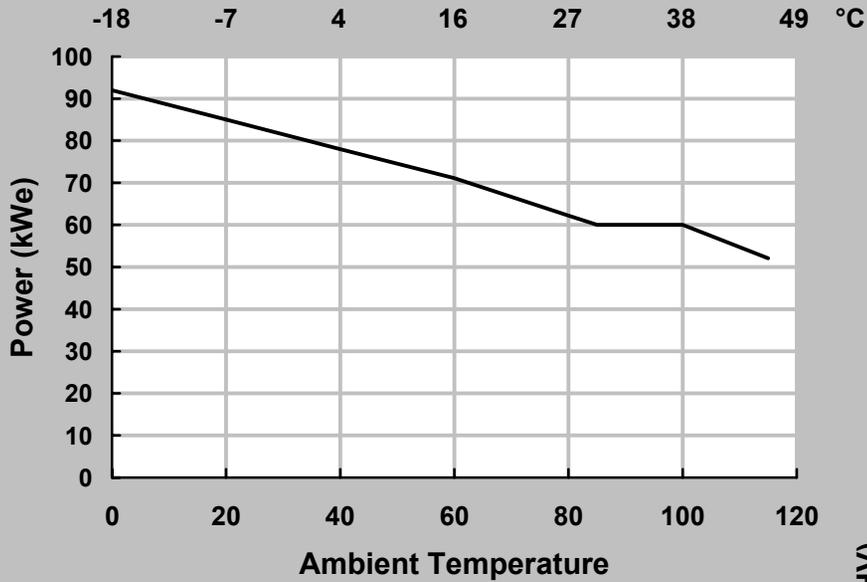


70kW Specifications

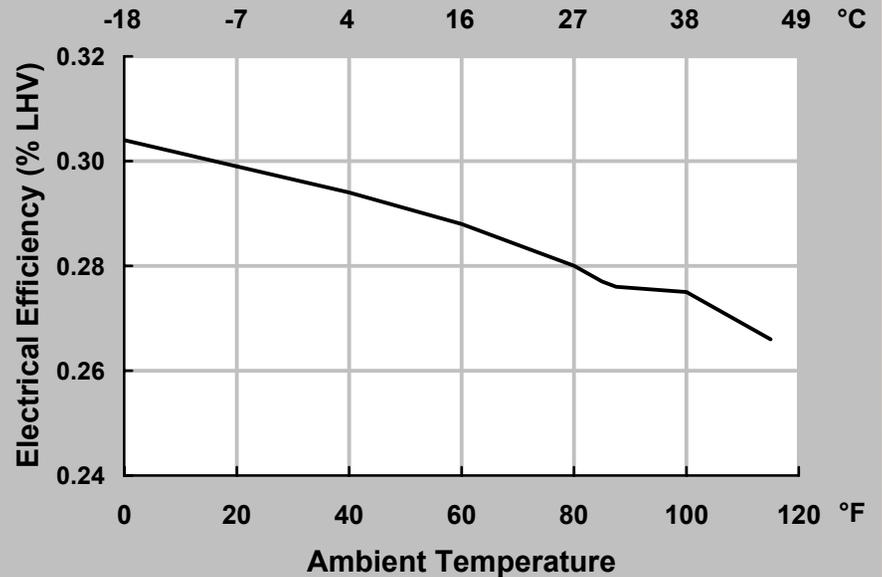


- **70kWe model**
- **Has 130% peaking power capacity on cold days (92 kWe)**
- **Efficiency**
 - Induction system: 29% LHV electric (28% w/booster)
 - Synchronous system: 28% LHV electric (27% w/booster)
 - Up to 70% total with cogeneration
- **Low emissions with natural gas**
- **8,000 hour maintenance interval**
- **80,000 hour engine life**
- **Grid-parallel or grid-isolated electrical generation**
- **Closed transitions to grid-isolated mode during grid outages**
- **Automatic block load handling up to 70kW**

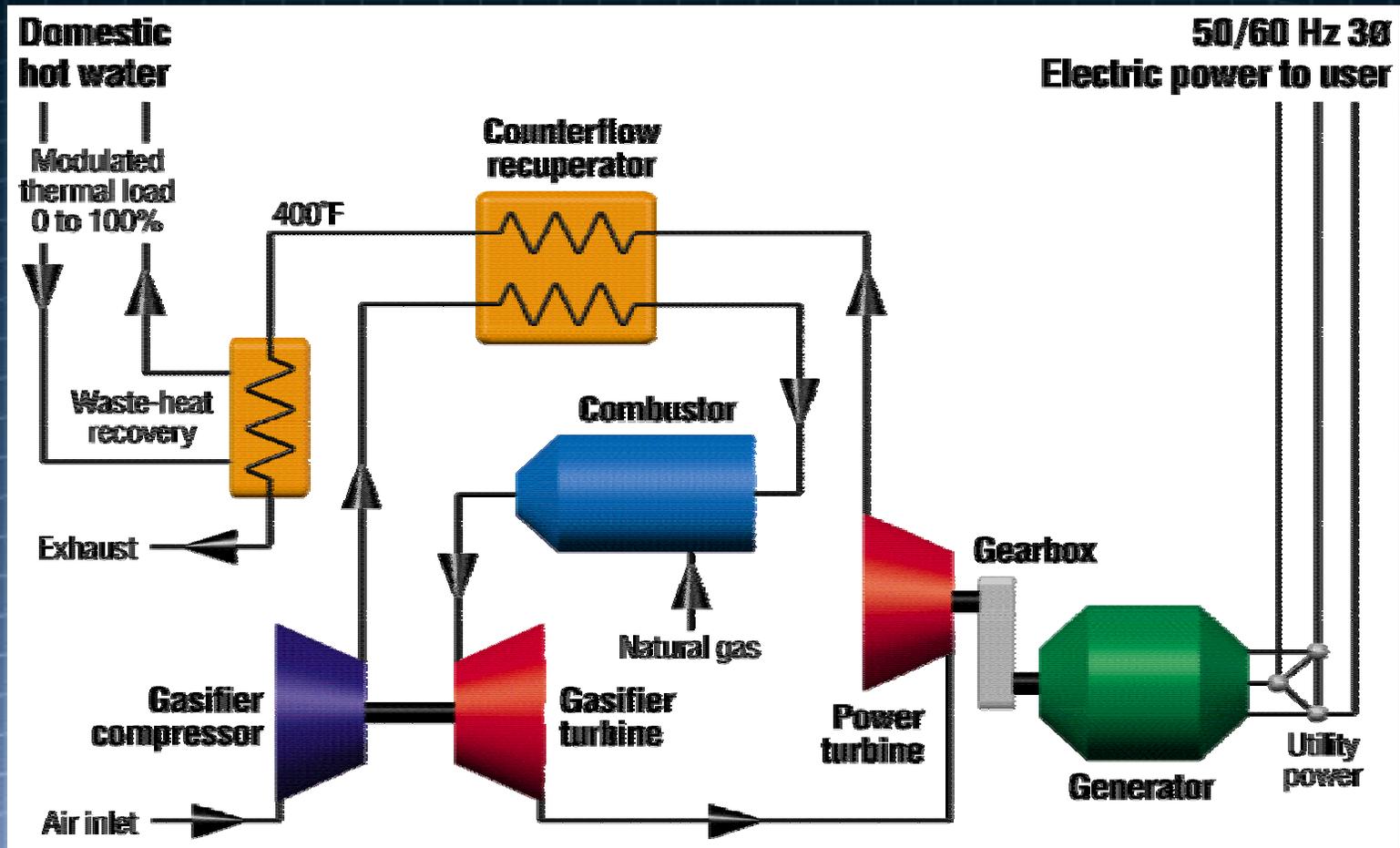
70kW Performance (Induction)



Note: KWe is electrical output at terminals corrected for parasitics, but not including gas booster power.



System Cycle Diagram

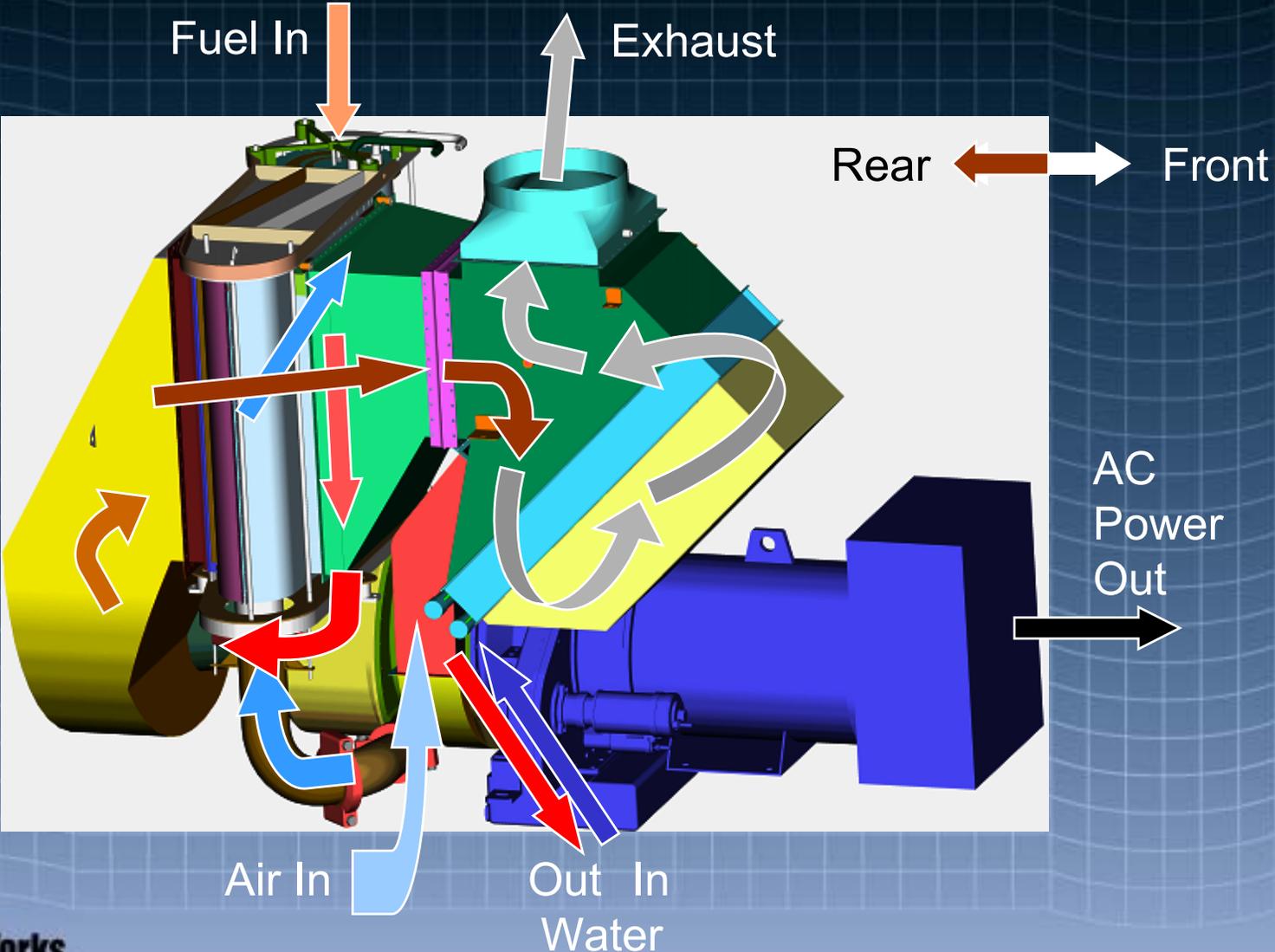


250kW Specifications



- 250kWe model at ISO conditions
- Has 120% peaking power capacity on cold days (300 kWe specified)?
- Efficiency
 - 31% LHV electric w/o booster
 - Up to 70% total with cogeneration
- Low emissions with natural gas
 - <9 ppmv NOx @ 15% excess O₂
- 8,000 hour maintenance interval
- 80,000 hour engine life
- 3x footprint of 70kW
- Grid-parallel or grid-isolated electrical generation (synchronous gen.)
- Closed transitions to grid-isolated mode during grid outages
- Engine principally handles block load changes alone

Prime Mover Configuration



Davidson, NC Final Assembly



Assembly Area



IR's US Service Coverage



Codes Used in Development

- **UL 2200** **Stationary Engine Generator Assemblies**
- **NFPA 37** **Stationary Combustion Engines**
- **NFPA 54** **National Fuel Gas Code**
- **NFPA 70** **National Electric Code**
- **EGSA** **Safety Codes Required by States & Major Cities**
- **ANSI / NSF 51** **Standard for Food Equipment**
- **ANSI C84.1** **Electric Power Systems & Equipment Voltage Ratings**
 (60Hz)
- **ANSI 133.8** **Gas Turbine Installation Sound Emissions**
- **ANSI 133.9** **Measurement of Exhaust Emissions From**
 Stationary Gas Turbine Engines
- **ANSI B133.10** **Gas Turbine Information to be Supplied by User**
 and Manufacturer
- **EPA Section 1417** **Safe Drinking and Water Act**
- **CSA C22.2 #100** **Motors and Generators, Industrial Products**
- **OSHA 1910.95** **Occupational Noise Exposure**
 - **.101** **Compressed Gases**
 - **.144** **Safety Color Codes for Physical Hazards**
 - **.145** **Signs and Tags**
 - **.146** **Permit Required Confined Spaces**
 - **.147** **Control of Hazardous Energy**

Other Codes That Can Apply

- UL1741 - Converters / Inverters / Charge Controllers For Independent Power Systems
- Existing Electrical Interconnect Standards
 - NY: PSC Standardized Interconnect Requirements ...
 - CA: Rule 21
 - Future:
 - o IEEE Std1547 National Interconnect
 - o FERC Small Generator Interconnect NOPR
 - o MA: Collaborative Interconnection Tariff
- Major building codes :
 - National Building Code
 - Uniform Building Code
 - Standard Building Code
- US EPA, State, and Local Emissions Requirements

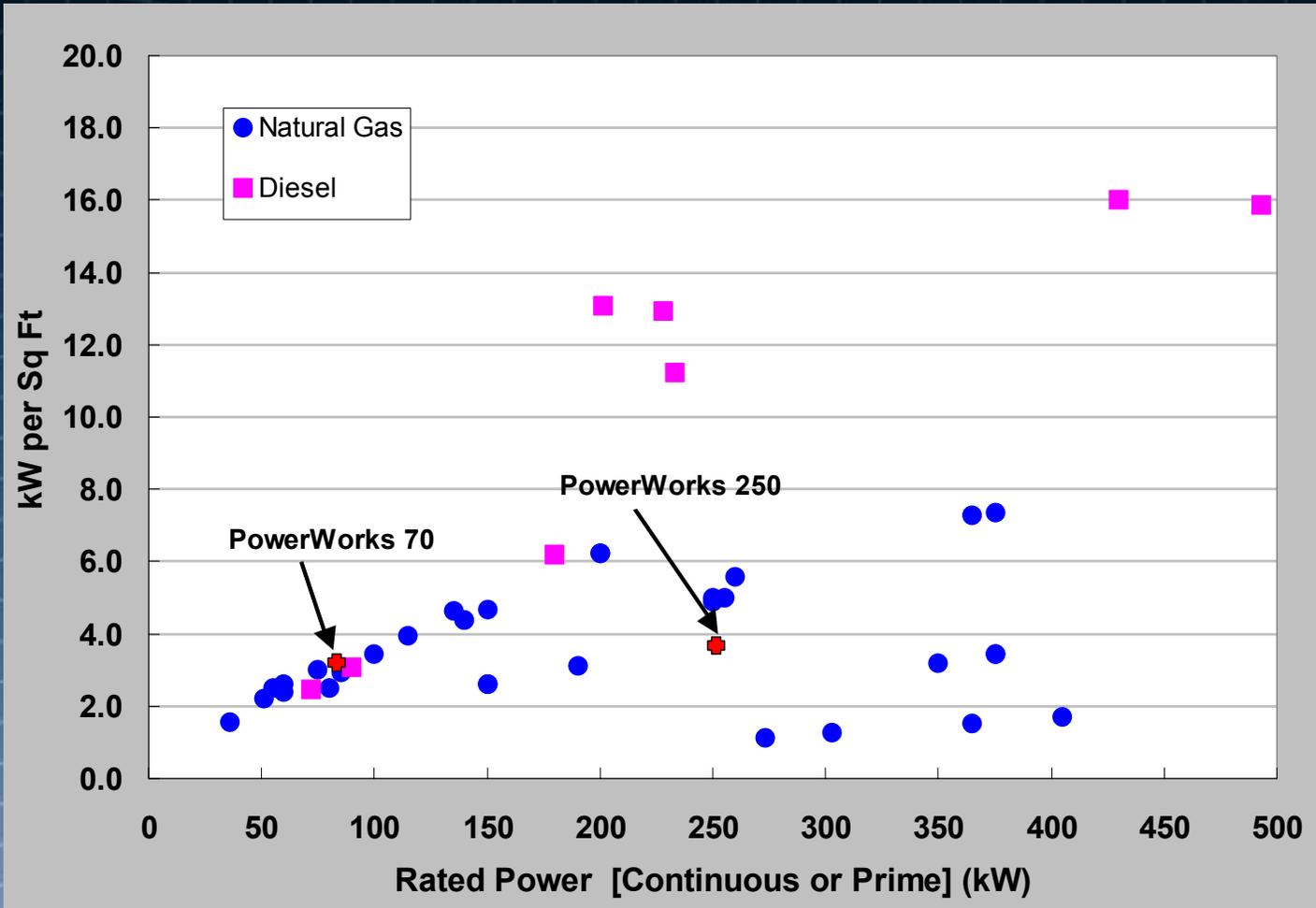
Packaging

- Qualified for indoor use
- Low noise level: 78DbA @ 1 meter
- Built-in industrial controls
- Special foundation not required
- Independent inlet air ducting
 - 1100 to 1500 scfm typical
 - Cool, filtered air preferred
 - Consider using building exhaust



69L x 42W x 87H in (175L x 107W x 221H cm)
4100 or 4850 pounds (1860 or 2200 kg)

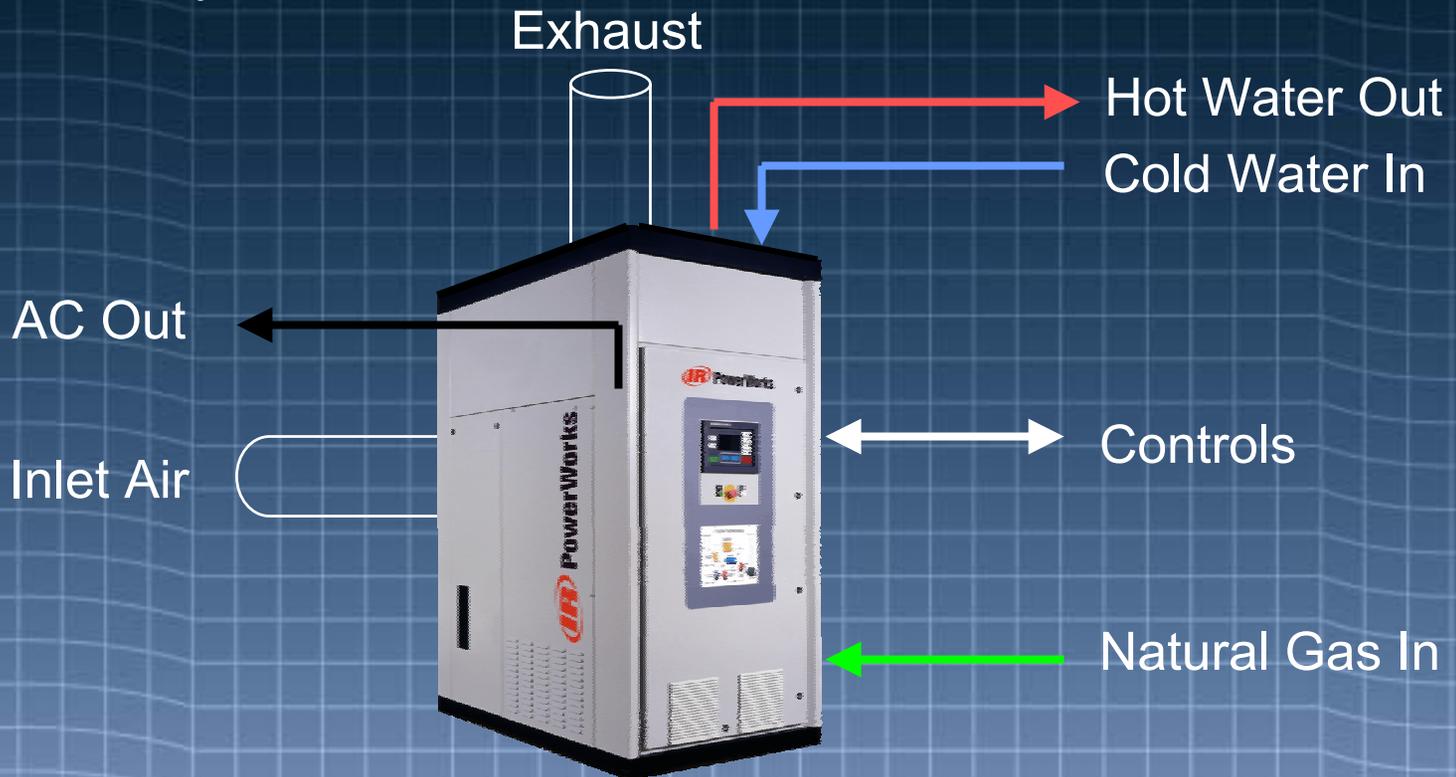
“Footprint” Comparison



“Prime” or “continuous” duty power ratings @100% load
Based on Manufacturer’s published specifications

Facility-Microturbine Integration

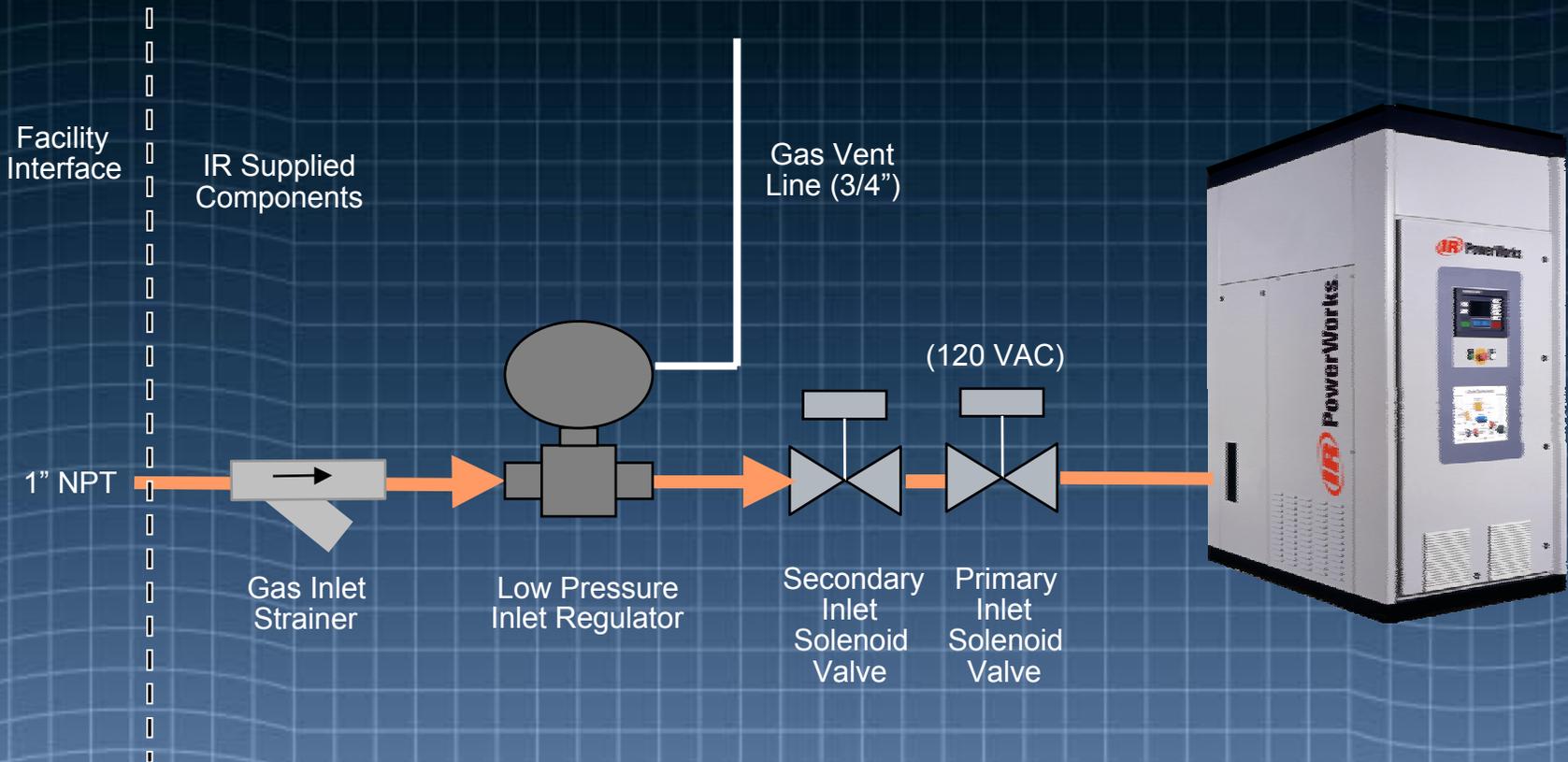
Physical Layout



Typical Indoor Installation



Natural Gas Input



- Sealed fuel handling system
- Minimum inlet pipe pressure = 0.29 PSIG
- Minimum flow = 52.9 lbm/hr

Ingersoll-Rand's LFGTE solutions

The EcoWorks™ Landfill Gas Microturbine System

- A completely integrated package consisting of Ingersoll-Rand components
- One or more microturbines (70 kW or 250 kW increments)
- Fuel conditioner (sized for total rated capacity of plant)
- All required facility interface components

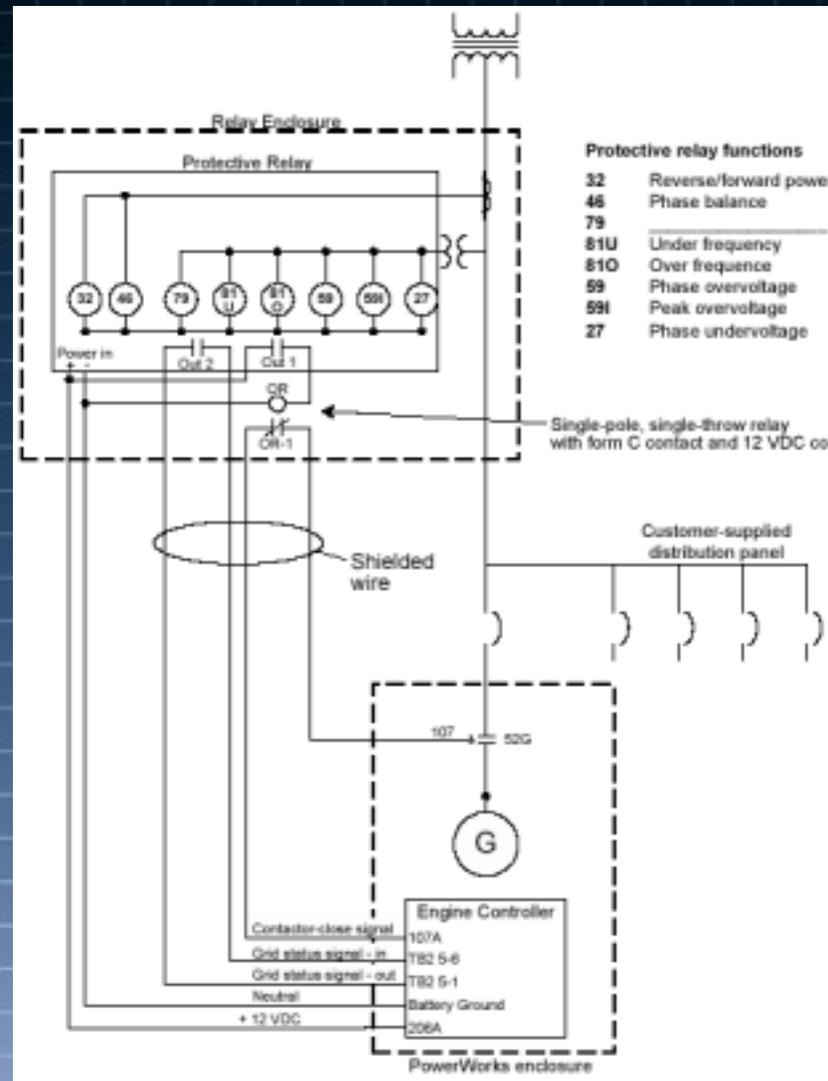


Fuel Conditioner

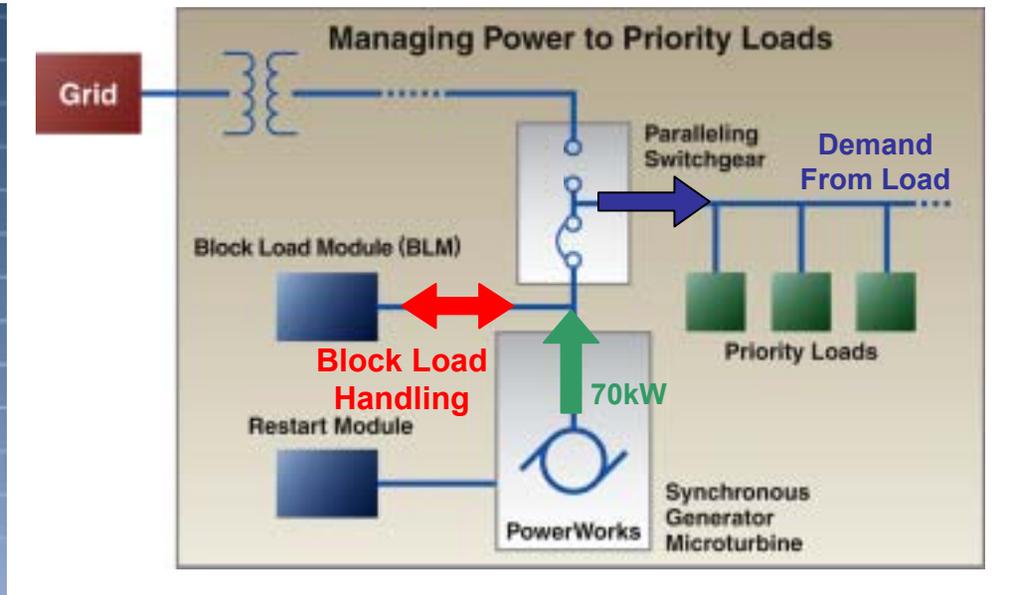
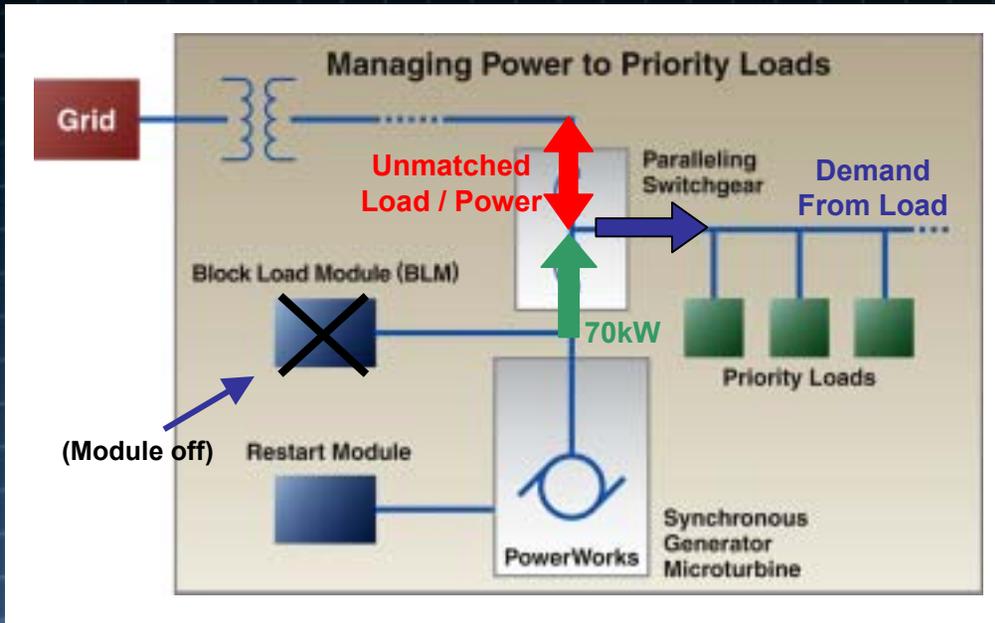
- Complete package supplied by IR
- Compressor, dryer, gas purification
- Factory assembled for reliability and low cost
- Removes water, siloxanes, other impurities
- Simple installation
 - Piping and wiring
- Full IR warranty and service



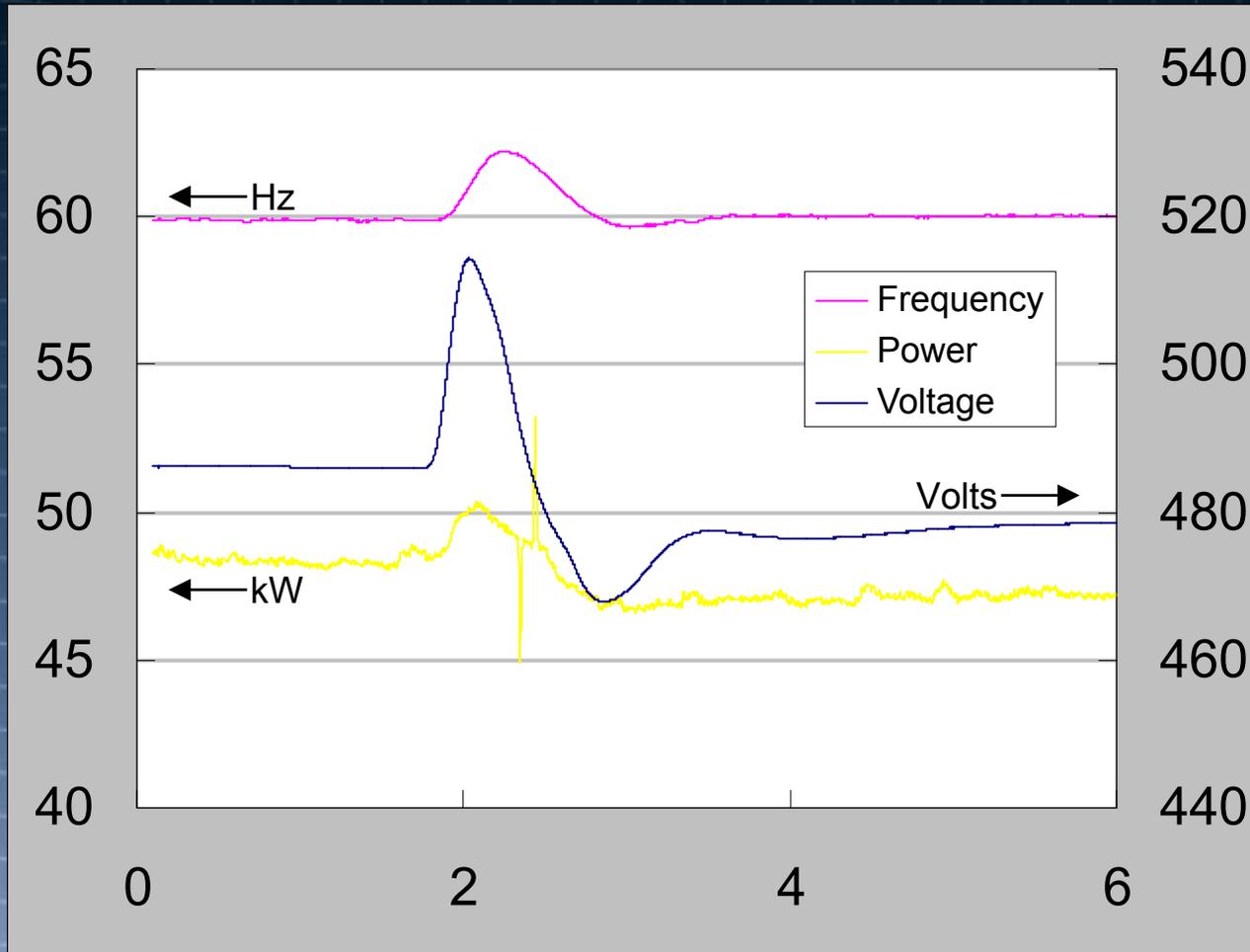
Simple Intertie Electrical Interconnect



Synchronous System Capability



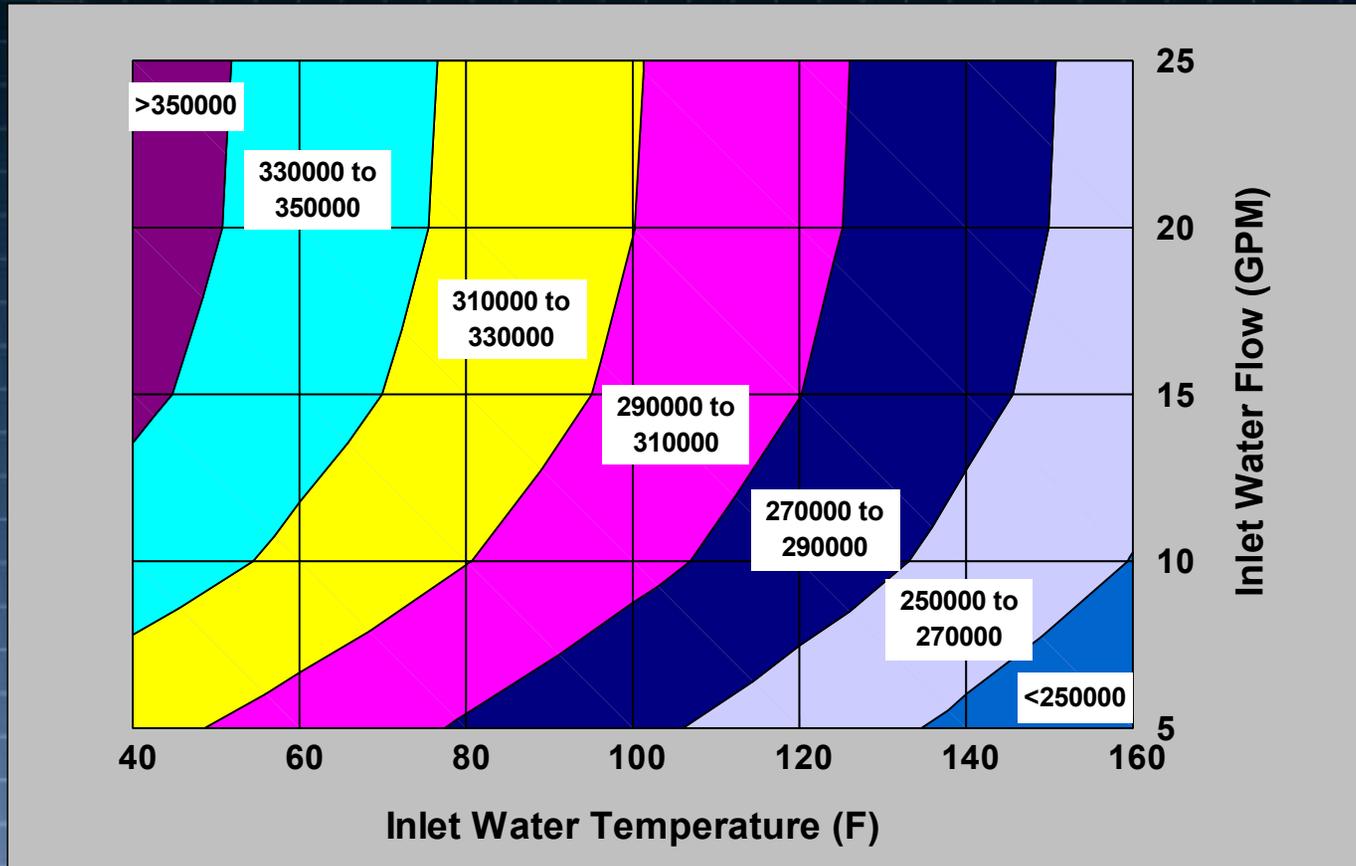
Grid-Parallel To Grid-Isolated Detail



Fully Integrated Heat Recovery System

- Built into exhaust plenum immediately after recuperator
- Designed for heating water
 - 6 to 26 gpm (70kW microturbine)
 - Up to 200°F water output
 - Suitable for potable water up to 125 psig
 - Example: 278,000 BTU/hr @ 20GPM with inlet water temperature of 140°F
- Heat can also be recovered directly from exhaust
 - About 421°F after recuperator
 - Very clean, perhaps cleaner than input air!

Heat Recovery Output BTU/hr



- Recovered BTU/hr depends on inlet temperature and flow rate

Applications

Customer Motivations

Cost Savings

Power Availability

Power Generation

Power Quality

Environ. Compliance



Typical Application Segments

Agriculture,
Hotel,
Chemical

Health Care,
Universities,
Food Distrib.

Landfill,
Mining,
Wastewater

Communication,
IT,
Hi-Value Mfg

Petroleum,
Process,
Materials

Type of Service

Cogeneration	✓	✓	✓		✓
Peak Shaving	✓	✓	✓		✓
Prime Power			✓	✓	✓
Running Backup	✓	✓		✓	
Remote Power			✓	✓	

Typical Power Needs For Facilities

- Convenience Stores 40 to 50 kW
- Fast Food 40 to 50 kW
- Restaurant Chain 50 to 70 kW
- Filling Stations 50 to 70 kW
- Box Stores 200 to 400 kW
- Older Supermarkets 150 to 300 kW
- Landfills 500kW (gas equiv)
- New Supermarkets 300 to 2,000 kW
- Hospitals 100 to 6,000 kW
- Hotels 200 to 2,500 kW
- Large Office Buildings 400 to 3,000 kW
- Universities 1,000 to 4,000 kW
- Factories 500 kW and up
- Waste Treatment 1.5 to 10MW

Applications - Community Center



- Skilled nursing facility located in NY
- 60,000 sqft facility
- PowerWorks generates hot water that provides most of the facility's Domestic Hot Water (DHW) needs
- Installed in new outside building
- Natural gas fuel
- 24/7 electricity (base load)



Applications – Landfill

- Jamacha landfill, San Diego, CA
- Small, closed municipal landfill
- Installed in newly roofed area
- Low BTU fuel from degradation of biological waste (28 to 38% methane)
- 24/7 electricity (base load) exported to grid
- No operator on-site



Applications – Landfill



- OII (Operating Industries), Monterey Park, CA
- Inactive super-fund toxic waste landfill site
- Constant flaring at ~24% methane content
- Six PowerWorks units operating at 38-40%
- Exhaust gases are flared to ensure complete burning of gas (99.99% DE)
- Powers flare station and leachate treatment



Applications - Landfill

- Butterfield landfill, Phoenix, AZ
- One 70 kW unit to burn LFG @ 40% CH₄
- Will power landfill's onsite requirements
- Exports excess power to Arizona Public Services Company
- All equipment is mounted on a single skid
- Includes remote monitoring



Applications - Greenhouse

- Claims highest yield of roses per sq-m in the world
- Winter: electricity defers sun lamps load
- Summer: electricity defers heat pumps load
- Recovered heat used to warm plant beds



Applications - Industrial



- LCN - Division of IR Security & Safety in Illinois
- Offers heavy-duty fire/life/safety door closers
- Reservoir pumps city water to the microturbines which heat the water for use in a five-stage parts washing process
- Natural gas fuel input

